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TITLE: EVOLUTION OF CEPHEIDS WITH PULSATIONALLY DRIVEN MASS LOSS

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Evolution of Cepheids with Pulsationally-driven Mass Loss

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Abstract

We have run models of intermediate mass stars (5, 6, 7, and 8 $M_{\odot}$ with $Y=0.28$, $Z=0.02$) with pulsationally-driven mass loss occurring in the Cepheid instability strip. We used the new $^{12}C(\alpha,\gamma)^{16}O$ rates of Caughlan et. al. (1985). The enhanced rate extends the tip of the blue loop, allowing the 5 and 6 $M_{\odot}$ models to re-enter the Cepheid strip, unlike the models calculated using the old rates (Becker, 1981). We attempted to see if mass loss during the Cepheid stage could redden the tip of the blue loop sufficiently to place it inside the instability strip, thereby "trapping" the star, and allowing it to lose mass for a period of time significantly longer than the normal crossing time. Our results show that this mechanism does in fact work for a 7 $M_{\odot}$ star with mass loss rates as low as $\sim 5\times10^{-7}$ $M_{\odot}$ yr^{-1}. Observations of P-Cygni profiles in Cepheids indicate that this rate is not unreasonable. This behavior acts to reduce the discrepancy between the evolutionary and pulsation-derived masses for Cepheids. Another consequence is that the rates of period change are decreased, bringing them into better agreement with observed values.

I. Introduction

It has been proposed by Lee Anne Willson and George Bowen (1984) that variable stars may experience pulsationally-driven mass loss. We have attempted to study the effects on intermediate mass star evolution of mass loss in the Cepheid instability strip. We evolved 5, 6, 7 and 8 $M_{\odot}$ models of Population I composition ($Y=0.28$, $Z=0.02$). We used the definition of the location of the Cepheid instability strip provided by Iben and Tuggle (1975). The mass loss parameterization is given below:

$$\dot{M} = 5 \times 10^{-8} * (L/1000) * (R/35.0)^2$$

where L and R are the luminosity and radius in solar units.
Observational evidence for Cepheid mass loss (Welch and McAlary, 1986 and Deasy and Butler, 1986) have large uncertainties and depend strongly on assumptions regarding the structure of the wind, but give rates in the range of 10^{-5} to 10^{-9} $M_\odot$ yr^{-1}.

II. Reaction Rates

We first studied the differences in Cepheid evolution caused by using the new reaction rates without mass loss. (For more information on the effects of mass loss on Cepheid models with the old reaction rate, see Brunish, Willson and Becker, 1986). The new rates cause the tip of the blue loop to be considerably bluer for the 5, 6 and 7 $M_\odot$ models, compared to the models of Becker (1981). Thus, models which only had one crossing of the Cepheid strip now have at least three crossings and perhaps five. The pulsational periods for the models are considerably changed also, becoming quite a bit shorter for a given mass than those derived using the old rates. With the old rate a 6 $M_\odot$ model has a period of about 8 days, while the same model with the new rate has a period of only 5 days. This is because the new rate causes the models to be more luminous for a given mass and effective temperature.

Table I

Effect of $^{12}C(\alpha,\gamma)^{16}O$ rate on blue loops

	Blue Tip (old rates)		Blue Tip(new rates)	
Mass	log T_e	log $L/L_\odot$	log T_e	log $L/L_\odot$
5 $M_\odot$	3.665	3.013	3.763	3.078

6 $M_\odot$			3.882	3.453
7 $M_\odot$	3.875	3.670	3.992	3.752
8 $M_\odot$			3.959	3.941

III. Mass Loss

Inclusion of mass loss while the models are in the Cepheid strip caused the tips of the blue loops to be reddened, bringing them back closer to the blue edge of the strip for the 7 and 8 $M_\odot$ models. For all the models the time spent in the strip increased with mass loss, with a concomitant decrease in the rate of period change (dP/P). The luminosities were only slightly decreased. The amount of mass lost while crossing the strip was about 2 to 10%.

Table II

Effect of Mass Loss on blue loops

	Blue Tip(no mass loss)		Blue Tip(mass loss)	
Mass	log T_e	log $L/L_\odot$	log T_e	log $L/L_\odot$
5 $M_\odot$	3.763	3.078	3.761	3.083
6 $M_\odot$	3.882	3.453	3.808	3.392
7 $M_\odot$	3.992	3.752	3.963	3.732
8 $M_\odot$	3.959	3.941		

IV. Conclusions

Postulated mass loss due to a pulsationally-driven wind that occurs while stars are in the Cepheid instability strip causes evolutionary models to evolve more slowly with lower masses but only slightly lower luminosities. This results in shorter periods and considerably smaller rates of period change for Cepheids observed at a given luminosity. Therefore these models are in better agreement with observed rates of period change and with pulsational masses determined for Cepheids than standard models.

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